COMPARING WIND DIRECTIONS ESTIMATED FROM DUST DEVIL TRACKS ANALYSIS WITH WIND DIRECTIONS PREDICTED BY THE MARS CLIMATE DATABASE (MCD).

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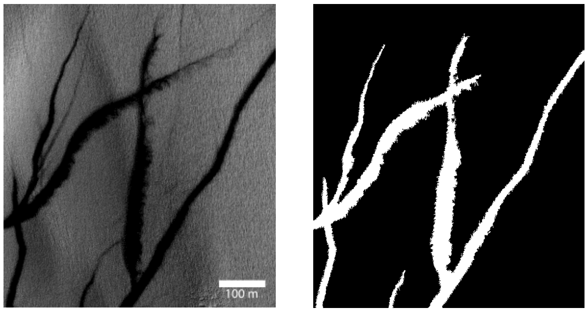
Introduction: Dust devil tracks (DDT) are albedo patterns on planetary surfaces that result from the removal of particles by the presence of a dust devil to expose an underlying surface with a different albedo. On Mars, dust devil tracks densities were shown to change with the time of the year, suggesting that dust devil activity also depends on the season of the year [1-2]. Those albedo features tend to fade with time, which is attributed to the deposition of dust [3-4]. An important information that can be obtained by the analysis of the tracks is the trajectory of the vortices, which can be used to infer the wind orientation near the surface, as dust devils are typically thought to move, on average, in the direction of the prevailing wind [5]. To verify the validity of this assumption, we have calculated the main direction of dust devil tracks delineated in 200 images and compared them with the Mars Climate Database (MCD) predicted wind directions using Directional Morphological Openings by Linear Structuring Elements (LSEs), as proposed by [6].

The MCD: The MCD is a database of atmospheric statistics compiled from the Global Climate Model (GCM) and respective numerical simulations of the Martian atmosphere. It was developed by the Laboratoire de Météorologie Dynamique (LMD, Paris), Atmospheric, Oceanic and Planetary Physics group (AOPP, Oxford), Department of Physics and Astronomy (The Open University) and Instituto de Astrofísica de Andalucía (IAA, Granada) with the support of the European Space Agency and the Centre Nationale d'Estudes Spatiales [7].

Image dataset: The input for the method is a binary image showing detected dust devil tracks in white and the background in black. Dust devil tracks were previously detected in 200 images using the method proposed by [8], with a global accuracy of 92% ±5%. Originally, the dataset contained 124 images (75 MOC narrow angle panchromatic band and 49 HiRISE red band). Some of them were cropped into several regions of interest, making the dataset equal to 200 images (90 MOC and 110 HiRISE).

Method: We have used binary images with previously detected tracks [8] as input. The morphological opening γ of f by a LSE B is the erosion ε of f by B followed by a dilation δ by B transposed: $\gamma_B(f) = \delta_{\check{B}}(\varepsilon_B(f))$ with B being defined here as a function of size λ and direction α. Size λ varied from scene to scene (though, for each scene, the size was fixed) according to the maximum width of the tracks in each scene. Tracks width had been calculated as described in [8]. The directions considered were: 0°-180°, 15°-195°, 30°-210°, 45°-225°, 60°-240°, 75°-255°, 90°-270°, 105°-285°, 120°-300°, 135°-315°, 150°-330° and 165°-345°, measured clockwise from North. The main direction of the tracks is assumed to be the one in which the opening has removed less pixels than in the other directions. The global accuracy of the method is ~86°.

As an example, Fig. 1 shows a region of the HiRISE image PSP_006163_1345 (a) and the result of the automated track detection used as input image (b). For that scene, the main dust devil tracks direction calculated by directional morphological openings by LSEs was 30°-210° (counted clockwise from North).



(a) (b)

Figure 1. Region of HiRISE image PSP_006163_1345 (a); Automated tracks detection (b). [Original image credits: NASA/JPL/University of Arizona].

Results: The method has been applied to the set of 200 MOC and HiRISE images (from quadrangles Aeolis, Noachis, Argyre, Eridania and Hellas). Table 1 shows the directions calculated for images of Noachis quadrangle (second column), and the directions of the winds simulated by the MCD (third column). The simulations were done according to the solar longitude, acquisition date and time, latitude and longitude of each scene, inside the Martian boundary layer.

Table 1.Wind directions (Noachis)

Noachis Images	Calculated	Simulated
PSP_002548_1255_P1	120°	75°
PSP_002548_1255_P2	60°	75°
PSP_002548_1255_P3	120°	75°
PSP_003326_1255	75°	75°
PSP_004038_1255	75°	135°
PSP_004249_1255	15°	135°
R0903467	135°	165°
S09-01660_P1	165°	165°
S09-01660_P2	165°	165°
S09-00929_P1	0°	165°
S09-00929_P2	165°	165°
ESP_013321_1175	135°	150°
ESP_013557_1245	165°	165°
E11-01722	30°	165°
E11-03103	0°	165°
E11-00747	30°	150°
E11-01129	90°	150°
E11-01527	60°	150°
E11-03844	30°	150°
E11-02963	15°	150°
E11-00582	45°	150°
E11-01314	0°	165°
R10-04224	165°	150°
R10-02844	165°	165°
R10-04196	30°	165°
R10-00382	150°	165°
R11-03714	15°	150°
PSP_005238_1255	120°	135°
PSP_005383_1255	0°	120°
PSP_005528_1255	105°	120°
ESP_013992_1170_P1	0°	150°
ESP_013992_1170_P2	15°	150°
ESP_013992_1170_P3	30°	150°
ESP_014020_1150	30°	165°
ESP_014322_1215	15°	135°
PSP_005659_1335_P1	15°	75°
PSP_005659_1335_P2	0°	75°
PSP_005659_1335_P3	0°	75°
E12-01041	150°	165°

In Table 1, when we compare the wind directions inferred from dust devil tracks with the simulated wind directions, only ~41% of the values agree inside a tolerance of 15° (which was the step used in the directions measurements). If we consider 30° and 45° of tolerance, we have ~44% and ~49% of matches. When we consider the whole set of 200 images, only 35% of the measurements agreed with the simulations. The results obtained for the other 4 quadrangles were similar, not showing a concordance between calculated and simulated directions of the wind. We have found 20% for Eridania, ~42% for Argyre, 20% for Aeolis and 35% for Hellas, considering a 15° tolerance.

Conclusions: The dataset we have built and for which we have calculated the main direction of dust devil tracks (200 images) to compare with the Mars Climate Database (MCD) predicted wind directions using Directional Morphological Openings by Linear Structuring Elements (LSEs), covers many areas in 5 quadrangles (Aeolis, Argyre, Eridania, Noachis and Hellas) and can be considered representative of the diversity of situations. Nevertheless, for the whole set, only 35% of the wind directions estimated from the analysis of dust devil tracks agreed with the wind directions simulated by the MCD, considering a tolerance of 15°. When adopting a higher tolerance (30°) for the difference between measurements and simulations, ~50% of the observations agreed, which cannot still be considered a relevant value. Thus, this is an indicative that the MCD fails to predict local wind patterns. Therefore, for a more local scale, the main wind direction should be inferred by methods other than the MCD simulations, namely from the analysis of the DDT main orientations. For that purpose, a systematic collection of data from DDT should be performed, specifically from several representative sites in several time periods.

References: [1] Thomas et al. (2003) *Icarus* 162, 242-258. [2] Whelley et al. (2006) *JGR* 111, E10003. [3] Malin M. et al. (2001) *JGR* 106, E10. [4] Balme M. et al. (2003) *Rev. Geophys.* 44, RG3003. [5] Rennó et al. (1998) *J. Atmos. Sci.* 55, 3244-3252. [6] Statella et al. (2014) *Advances in Spaces Research* 53, 1822-1833. [7] Lewis et al. (1999) *J. Geophys. Res. Planets* 104(E10). [8] Statella et al. (2012) *PSS* 70, 46-58.